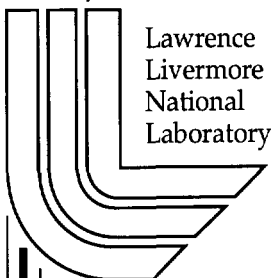


Measurement of Low Level Explosives Reaction in Gauged Multi-Dimensional Steven Impact Tests

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MEASUREMENT OF LOW LEVEL EXPLOSIVES REACTION IN GAUGED MULTI-DIMENSIONAL STEVEN IMPACT TESTS

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Abstract. The Steven Test was developed to determine relative impact sensitivity of metal encased solid high explosives and also be amenable to two-dimensional modeling. Low level reaction thresholds occur at impact velocities below those required for shock initiation. To assist in understanding this test, multi-dimensional gauge techniques utilizing carbon foil and carbon resistor gauges were used to measure pressure and event times. Carbon resistor gauges indicated late time low level reactions 200-540 μ s after projectile impact, creating 0.39-2.00 kb peak shocks centered in PBX 9501 explosives discs and a 0.60 kb peak shock in a LX-04 disk. Steven Test modeling results, based on ignition and growth criteria, are presented for two PBX 9501 scenarios: one with projectile impact velocity just under threshold (51 m/s) and one with projectile impact velocity just over threshold (55 m/s). Modeling results are presented and compared to experimental data.

INTRODUCTION

Impact sensitivity of solid high explosives is an important concern in handling, storage, and shipping procedures. Several impact tests have been developed for specific accident scenarios, but these tests are generally neither reproducible nor amenable to computer modeling. The Steven Impact test¹ was developed with these objectives in mind. Blast wave overpressure gauges and external strain gauges were initially used to measure the relative violence of the explosive reactions. High-speed film was used, in part, to obtain time to reaction data. It became clear that adding embedded gauges to the experiment would enhance understanding of the ignition of explosives in this test

Modeling efforts based on Ignition and Growth reactive flow tested several impact ignition criteria and simulated the growth of explosive reaction following ignition as the confined explosive charge produced gaseous reaction products^{2,3}. The best models from these earlier works were used to model

the experiments containing the embedded gauges. This paper gives details of the embedded gauge experiments and modeling results.

EXPERIMENTAL GEOMETRY

Experimental geometry for the Steven impact test is shown in Fig. 1. A 6.01 cm diameter steel projectile is accelerated via a 76.2 mm gas gun into a cylindrical explosive charge of dimension 11 cm diameter and 1.285 cm thickness. The charge was confined using a 0.318 cm thick steel front plate, a 1.91 cm thick steel back plate and 2.67 cm steel sides. A Teflon retaining ring positioned the charge within the confinement vessel. Up to six external blast overpressure gauges were placed ten feet from the target for direct comparison with Susan test data. A variety of embedded pressure gauges measuring the internal pressure developed during impact and the subsequent growth of reaction and induced pressure if the critical impact velocity is exceeded are depicted. To date, only carbon foil and carbon resistor embedded gauges have been used.

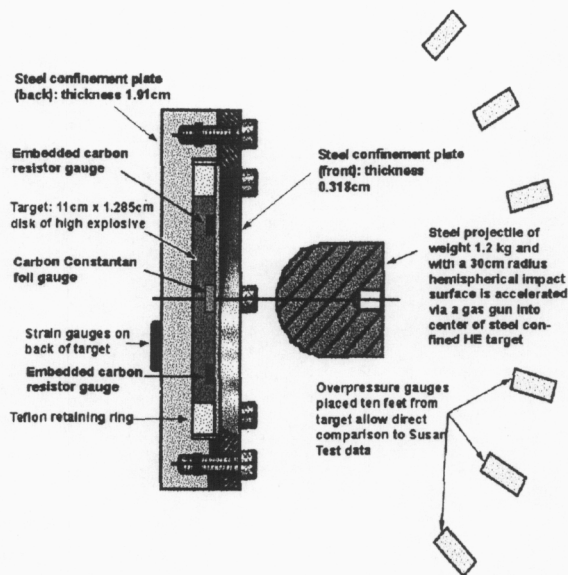


FIGURE 1. Schematic geometry of the Steven impact test.

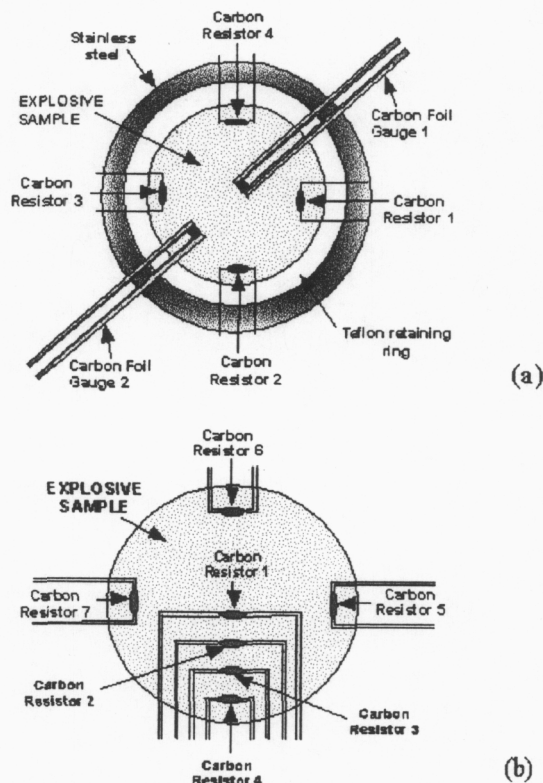


FIGURE 2. Cross-sectional view of embedded gauges inside the target for experiment #s (a) WRL 39-40, 43-47 and (b) WRL 121-122.

Figure 2 shows placement of the carbon foil and carbon resistor gauges in the targets. Two gauge layouts were used over the course of experiments. Figure 2(a) shows the resistor layout for WRL shot #s: 39-40, 43-47 and Fig. 2(b) shows the resistor layout for WRL shot #s: 122-123. The carbon resistors were placed into machined slots on the impact face of the explosive cylinder. The carbon foil gauges were sandwiched between two sheets of 0.125 mm thick Teflon. The Teflon initially extended over the entire diameter of the explosive. Later experiments eliminated the Teflon sheet and placed only a Teflon insulated gauge at the center.

The carbon foil gauge for one-dimensional longitudinal strain experiments⁴⁻⁶ is good for 0-30 kb pressures with 5-10% accuracy and typical temporal resolution of 25-115 ns. Some two-dimensional flow experiments have been fired using carbon foil gauges where strain compensation on the pressure signals was attempted⁶. The carbon resistor gauge^{5,7-10} is also good for one or two dimensional flow pressures of 0-30 kb with accuracy between 8-15%. The temporal resolution of the carbon resistor gauge is 1.4 μ s. It is a very rugged gauge that can be used in situations where the foil gauge will not survive. Accuracy decreases for high-end pressures due to the non-linear calibration curve of the gauge. Both gauges have large hystereses on release of pressure because they are porous materials that do not behave elastically.

For the foil gauge, the lower time resolution was determined by assuming a 25 μ m thick foil and the upper number assumed the foil gauge package to have insulation of 50 μ m layers on both sides of it i.e. a total package thickness of 130 μ m. The resistor gauge is assumed to have a 12.5 μ m glue layer on both sides of it. To reach equilibrium it was assumed that the principal wave and its reflections transited the gauge element five times [roughly 4 1/2 times the package thickness] at a nominal velocity of 5 km/sec.

EXPERIMENTAL RESULTS

Experimental results for the series of gauged Steven impact tests are shown in Table 1. Impact

TABLE 1. Summary of experimental results of the gauged Steven Impact Tests

| WRL Shot Number | HE type | Projectile Impact Velocity (m/s) | Projectile Impact Pressure—Carbon Foil Gauge (kb) | Late Reaction Peak Pressure - Carbon Resistor (kb) | Time of Late Reaction Peak (ms) | Comment |
|-----------------|-----------------|----------------------------------|---|--|---------------------------------|----------------------|
| 39 | PBX 9501 | 81.49 | - | - | - | Reaction observed |
| 40 | PBX 9501 | 61.06 | - | - | - | Reaction observed |
| 43 | LX-04 | 90.60 | 1.52 | 0.60 | 0.200 | Reaction observed |
| 44 | PBX 9501 (new) | 46.59 | 0.59 | 0.15 | - | No Reaction observed |
| 44-2 | PBX 9501 | 46.00 | - | 0.18 | - | No Reaction observed |
| 45 | PBX 9501 (new) | 51.36 | 0.82 | 0.16 | - | No Reaction observed |
| 45-2 | PBX 9501 | 60.40 | 0.32 | 0.59 | 0.500 | Reaction observed |
| 46 | PBX 9501 (aged) | 55.40 | 1.17 | 2.10 | 0.540 | Reaction observed |
| 47 | PBX 9501 (aged) | 66.70 | 0.76 | 0.46 | 0.360 | Reaction observed |
| 121 | PBX 9501 | 49.50 | - | 0.17 | - | No Reaction observed |
| 122 | PBX 9501 | 55.57 | - | 0.39 | 0.315 | Reaction observed |

pressure histories provided by the carbon foil gauge records show no indication of fast energy release in any of the experiments. Carbon resistor gauges captured late time peak pressure data that were consistent with observed reaction/no-reaction determinations. Reactive collisions generally produced late time pressures greater than 0.35 kb, while shots with no reaction produced pressures less than 0.20 kb.

IGNITION AND GROWTH REACTIVE FLOW MODEL

Previous DYNA2D modeling¹⁻³ of the Steven test concentrated on its mechanical aspects, modifying the Ignition and Growth reactive flow model to calculate reaction rates under these impact conditions, normalizing these rates for various HMX-based explosives, and predicting threshold velocities for various projectile shapes. In this paper the pressures at the carbon foil and resistor gauge positions for impacts just below and above the threshold velocities for reaction in PBX 9501 are calculated and compared to the measured values. The teflon insulation on the embedded gauges

reduces the friction between the steel cover plate and the explosive charge resulting in slightly higher threshold velocities for reaction. This effect is modeled by reducing the Ignition coefficient slightly. Figure 3 shows the experimental and

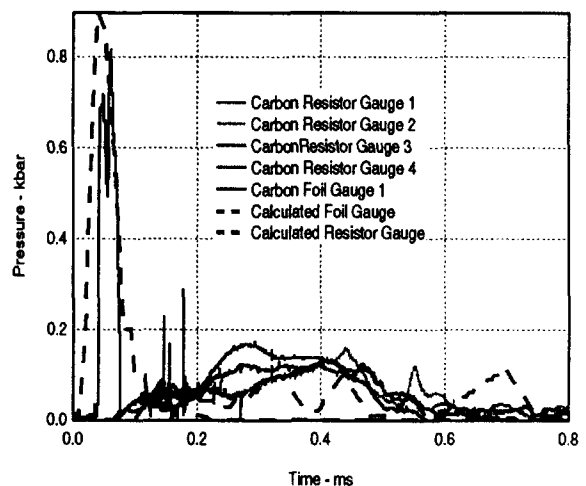


FIGURE 3. Comparison of embedded pressure gauge measurements and reactive flow calculations for WRL 45.

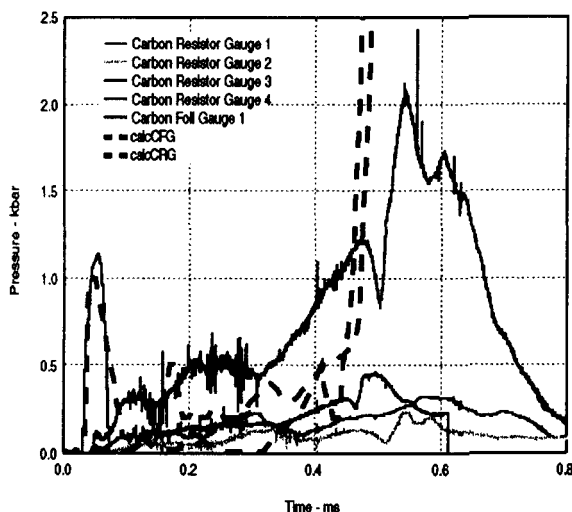


FIGURE 4. Comparison of embedded pressure gauge measurements and reactive flow calculations for WRL 46.

calculated pressure histories for an impact velocity of 51.36 m/s in experiment WRL-45, which did not cause a reaction. The calculated impact pressure and pulse duration agree closely with the carbon foil record. Figure 4 shows the comparison for reactive experiment WRL-46 impacted at 55.4 m/s. The calculated time to reaction and the pressures also agree well with this set of gauge records.

SUMMARY AND CONCLUSIONS

Both embedded carbon foil and resistor gauges gave repeatable pressure-time results in this Steven Test geometry. The carbon resistor gauge is rugged but requires several microseconds to come to equilibrium with its surrounding material. Its pressure measurements are not sensitive to the two-dimensional flow that occurs in this experiment because the gauge smoothes out the differences giving only the change in resistance. Future work includes: (1) hydrodynamic code calculations to calculate lateral strain effects; (2) lateral strain measurements with a strain gauge located near carbon foil active stress element, and (3) an analysis of carbon foil gauge response to strain.

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